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ANTICYCLOGENESIS IN RELATION TO A PARTICULAR THICKNESS PATTERN

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Summary.—It is shown that a combination of a diffluent ridge and a confluent trough on the 1000–500-mb. thickness chart will give rise to sustained anticyclogenesis and, under certain conditions, to the formation of a new anticyclone.

Introduction.—Sutcliffe[1] has shown that development can be related to vorticity gradients indicated by the surface pressure and a thickness pattern representative of the horizontal temperature gradient in the troposphere. The 1000–500-mb. thickness chart is normally used in British practice and it has been shown that when:—

$$-\mathbf{V}' \frac{\partial}{\partial s}\left\{l + \zeta' + 2\zeta^{\circ}\right\} > \text{or} < 0$$

where $\mathbf{V}'$ = the thermal wind vector from 1000–500 mb.,

ζ' = the vorticity of the thermal wind for the 1000–500-mb. layer,

ζ° = the vorticity of the geostrophic wind at 1000 mb.,

l = the Coriolis parameter, $2\,\omega \sin \phi$

and $\frac{\partial}{\partial s}$ = differentiation along a thickness line,

then the situation favours either cyclogenesis or anticyclogenesis respectively. In a later work, Sutcliffe and Forsdyke[2] apply this to a study of the geometry of the thickness chart in a baroclinic atmosphere. Two of the patterns, the "diffluent ridge" and the "confluent trough" are shown in Figs. 1 and 2 respectively. The regions of maximum development are indicated by A for anticyclogenesis and C for cyclogenesis. If these two patterns are combined together as shown in Fig. 3 it will be noted that in the area between the trough and the ridge there is a region of anticyclogenetic tendency on both the warm and cold sides of the pattern. This common diffluent region will be referred to as the A–A region in the ensuing discussion. It is in this region that conditions favour the formation of an anticyclone.

The association of the rear of a confluent trough on the thickness chart with a surface ridge of high pressure is a common occurrence but, as Sutcliffe and Forsdyke[2] have mentioned, difficulty is usually experienced in deciding

how great the ridge development will be. We suggest that a combined diffluent-ridge confluent-trough pattern on the thickness chart in conjunction with the appropriate surface pattern will usually lead to the formation of a new anticyclone and in any event to large-scale ridging.

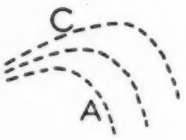


FIG. 1—DIFFLUENT RIDGE

FIG. 2—CONFLUENT TROUGH

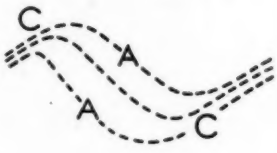


FIG. 3—COMBINED DIFFLUENT RIDGE AND CONFLUENT TROUGH

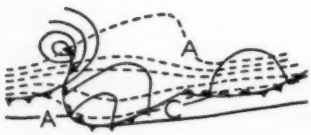


FIG. 4—DIFFLUENCE IN A WEST TO EAST DIRECTION

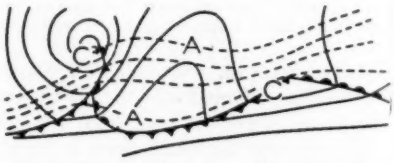


FIG. 5—DEVELOPMENT OF A DIFFLUENT RIDGE AND CONFLUENT TROUGH FROM THE DIFFLUENCE IN THE THERMAL STREAM

In the classical model of the general circulation of the atmosphere a sequence of depressions moves uninterruptedly from west to east in the unsettled westerly belt of temperate latitudes with inadequate room for new anticyclones to develop. Only temporary ridges are allowed for between successive depressions. In order to have anticyclogenesis of appreciable magnitude, it is essential to find some mechanism whereby this series of depressions can be interrupted[3]. The interruption is achieved by the combined diffluent-ridge confluent-trough pattern, since depressions associated with it are steered so that the distance between them is increased as the pattern develops. Space and time are thus available for the new anticyclone to form.

The developing pattern.—The pattern will form provided that there is a temporary diffluence in a strong west to east baroclinic zone, with depressions developing at the left exit of the western jet and the right entry to the eastern jet illustrated in Fig. 4. Subsequent advection and deepening of the depressions will bring into existence a model pattern shown in Fig. 5. With these requirements present the pattern will develop satisfactorily and produce an anticyclone if the conditions set out for its continuance are fulfilled.

Conditions for continued existence and development.—The important factors in the development process in this particular model are:—

(i) advection,

(ii) intensity of the pattern, $\mathbf{V}'\frac{\partial \zeta'}{\partial s}$ in the development inequality

and (iii) Coriolis effect, $\mathbf{V}'\frac{\partial l}{\partial s}$ in the development inequality.

Advection.—If the diffluent-ridge confluent-trough pattern is to produce a surface anticyclone it is vital that the advection of the air should be such as to maintain the pattern for a fair period of time, say 24 hr. The process is best illustrated with diagrams as in Figs. 6 and 7.

Low *a* shown in Fig. 6 has developed on the warm side of the confluent trough and moved quickly north-east, advecting cold air southwards and accentuating the confluent trough. A ridge has developed behind the depression in the rear of the confluent trough. This is the ridge which is often the problem in the determination of future development. Low *b* is in a tight thermal gradient approaching an area of diffluence. Therefore the tendency will be for it to swing to the left, but this will not occur if the advection is not suitable as will be seen from later considerations.

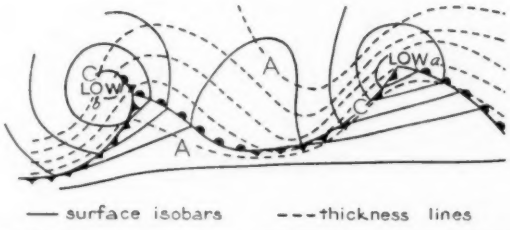


FIG. 6—INITIAL STAGE OF ANTICYCLONIC DEVELOPMENT

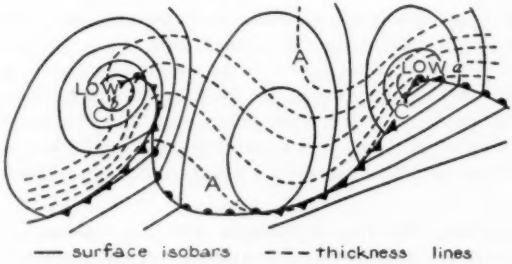


FIG. 7—DEVELOPMENT OF A SURFACE ANTICYCLONE

Low *b* shown in Fig. 7 is deflected to the left in the thermal diffluence on the west side of the diffluent ridge, low *a* continues to move quickly north-east in the strong thermal gradient of the confluent trough. This widens the gap between the two depressions giving an area A–A where anticyclogenesis—or

more strictly negative relative divergence, subsidence and probably anticyclogenesis—has time and space to exert itself, giving rise to further ridge development and eventually to an anticyclone. It should be noted that there is no restriction made on the deepening of lows *a* and *b*. The anticyclone, having developed in an already weak thermal field, will soon tend to become warm and barotropic and in many cases will bring about a change of type from changeable westerly to settled anticyclonic.

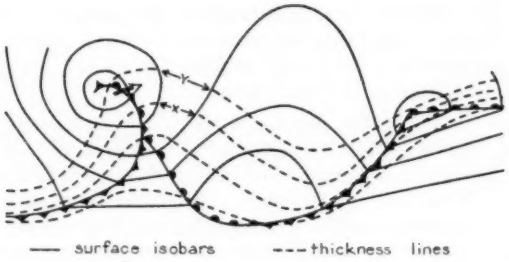


FIG. 8—TYPE OF ADVECTION LEADING TO CONFLUENCE OF THE THERMAL RIDGE

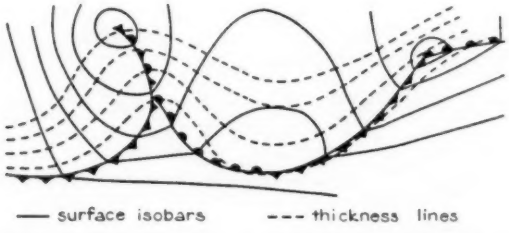


FIG. 9—RESULTING MOTION OF DEPRESSION ROUND THE PEAK OF THE CONFLUENT RIDGE

The deepening low *b* will advect warm air to high latitudes thus maintaining the strong thermal gradient on the western side of the thermal ridge. The deepening low *a* will maintain cold air advection southward on the eastern side of the confluent trough so that the A–A region will be maintained in the slacker thermal gradient between the ridge peak and the trough line. Once the high has developed it becomes an anticyclonic involution as described by Sutcliffe and Forsdyke[2]: the end result is a barotropic high with semi-permanent features.

Advection between the two depressions does not necessarily maintain the required thickness pattern. Only if the southerly gradient ahead of the western depression is tight will this occur. If the surface gradient is slack the ensuing advection will tend to lead to an extension of the thermal ridge peak eastwards rather than northwards as shown in Figs. 8 and 9.

In fact, adverse advection may cause the thickness pattern to resolve into a confluent-ridge confluent-trough or a confluent-ridge diffluent-trough. In Fig. 8 advection at X is greater than at Y. This, coupled with cooling due to

northward motion, will give rise to a tightening thermal gradient ahead of the depression which will then continue north-eastwards causing the surface ridge to collapse in the north as it proceeds. Eventually the thermal ridge will become confluent and the western depression will either turn the peak of the thermal ridge and move quickly south-east or become slow-moving with the formation of warm-front or warm-occlusion secondary depressions as described by Sawyer[4]. In the first case the southward advection of the cold air behind the depression will quickly cause the thermal ridge to collapse along with any associated anticyclone. In the second case the developing secondary depressions will move quickly towards the surface ridge producing a collapse in this manner. If the diffluent thermal ridge moves towards an area covered by snow the movement of the thickness lines will be retarded at the edge of the snow[5]. The thermal gradient will be increased since the lines of higher value will continue to be advected until they also approach the snow surface and the ridge will become confluent with resulting destruction of the anticyclogenetic pattern.

If southward advection of cold air in the confluent trough is not sufficiently great to keep the tight thermal gradient on its eastern side in existence, the pattern will be destroyed by the trough becoming diffluent and the essential A–A region being removed. Consequently, over the north-east Atlantic, it frequently happens that confluent troughs moving southwards do not persist due to the large amount of heating of the cold air in transit[6]. A similar effect is produced over the European continent in summer when surface heating is high. Occasionally, however, the advection of warm continental air northwards along the eastern side of a confluent trough helps to maintain it.

Advection of the right sort is therefore necessary to maintain the pattern. Ideally a strong south to south-east gradient should develop ahead of the western depression, low *b* in the diagrams, while a strong northerly gradient is maintained behind the eastern depression, low *a*.

If the confluent trough weakens after the surface anticyclone has formed, the A area on the cold side of the pattern vanishes and the anticyclone retreats south-westwards to the warm side leaving only a weakening ridge to the north-east. This corresponds closely with type IV of Sawyer's classification of anticyclones[7]. If the diffluent ridge becomes confluent the pattern is destroyed with resulting increased cyclonic activity as described above.

Development of a further depression on the warm side of the confluent trough is not frequent. Any depression which does develop will fill and move slowly away at right angles to the thermal stream over its centre. This is probably due to the large amount of subsidence in the cold air creating a vertically stable atmosphere in which small disturbances cannot develop[8].

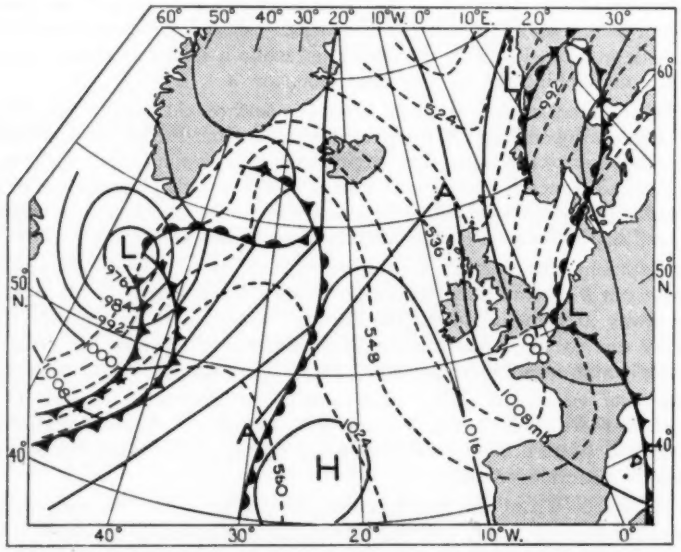
Intensity of the pattern.—The amount of anticyclogenesis depends on the strength of the thermal wind, $\mathbf{V}'$, and the gradients of thermal vorticity. A well defined pattern with moderate wind speeds is therefore necessary for significant anticyclogenesis.

Coriolis effect.—From the development inequality it can be seen that the effect of the Coriolis term, $-\mathbf{V}'(\partial l/\partial s)$, on anticyclogenesis is to reduce it when the A–A region has thickness lines orientated north to south and to increase it when the thickness lines are south to north, because $\partial l/\partial s$ is negative in the former case and positive in the latter. Since the latitude changes covered

by the pattern can be very large then the Coriolis term will play an important part in the development of surface features. In this particular pattern the effect is almost always one of reduction and can be large when the orientation of the thickness lines in the A–A region is north to south or when the pattern covers large latitude differences.

Assuming that the effect of the Coriolis term is sufficiently large to be worthy of consideration, since it is a reducing effect on anticyclogenesis, the smaller the Coriolis term, the greater will be the resulting development. The two things to be taken into account to reduce the value of the term are the mean latitude of the pattern and the orientation with respect to the earth's surface. Since $\partial l/\partial s$ is smaller in high latitudes than in lower latitudes a high mean latitude is to be desired for the greatest anticyclogenetic effect. If the thickness lines are orientated in a west to east direction the effect of the Coriolis term is zero, hence orientation in this direction of the thickness lines in the A–A region will be most favourable for the greatest anticyclogenetic effect. As the situation develops and the orientation is gradually changed from the most favourable to the least favourable with the A–A region lying north to south, there will be a period when the anticyclone will either decline slightly, or, at best, only maintain its intensity without further building until the thickness lines in the A–A region are orientated in the reverse direction at an appropriately small angle when further building will take place.

Steering.—The thermal wind over the new anticyclonic centre is usually not large and the thermal steering results only in a transfer of the larger pressure rises somewhat downstream along the thickness pattern.



— Isobars (1000-mb. contours) – – 500 - 1000 - mb. thickness lines

FIG. 10—CHART FOR OCTOBER 21, 1955 AT 0300 G.M.T.

Practical application to forecasting.—To use the diffluent ridge confluent trough for forecasting the formation of a new anticyclone, the following factors must be kept in mind:—

(i) Advection such as to keep the pattern in existence over a sufficiently long period.

(ii) Sharp diffluence on the ridge and confluence on the trough with sharp ridge and trough lines.

(iii) Orientation of the thickness lines in the A–A region should be near to the west-east direction and the thickness lines in the C areas should be near to the south-north direction.

(iv) The whole pattern should have a high mean latitude, say above 50°N.

If any one of the above conditions is not fulfilled, the intensity of the resulting anticyclogenesis will be reduced. A new anticyclone will not usually develop unless conditions (i), (ii) and (iv) are fulfilled, but other symptoms of anticyclogenesis, e.g. filling depressions, weakening fronts, will be manifest.

Characteristics of the development of anticyclones.—

(i) A depression on the thermal ridge is deflected to the left with much deepening, advecting warm air northwards.

(ii) A depression on the confluent trough moves north-east, advecting cold air southwards.

(iii) Any new depression developing on the confluent trough moves south-east at right angles to the thermal pattern and fills.

(iv) An anticyclone develops with marked tendency for two ridges orientated from A to A a little down the thermal pattern from the A–A axis.

(v) The large-amplitude pattern so generated gives a slight weakening of the anticyclone and then a re-build.

(vi) If a new model pattern is generated on the western side of an old high with a weakening pattern, then the tendency is for the centre to be transferred to the new A–A in the next 24 hr. and for this to become the major system.

(vii) The orientation of the A–A axis governs the future shape of an existing high even when a decline is indicated.

(viii) If the confluent trough weakens or the diffluent ridge becomes confluent the pattern is destroyed and the anticyclogenesis will be markedly reduced.

Examples of the use of the pattern in practice.—We give a number of examples of the various types of development in the synoptic situation which followed the appearance of a diffluent-ridge confluent-trough pattern on the 1000–500-mb. thickness chart. The developments which the foregoing theoretical discussion would have led one to expect, are given.

Development and orientation of a simple surface ridge.—On Friday October 21, 1955 at 0300 G.M.T. Fig. 10 shows a confluent trough lying from north to south over the British Isles backed by a large-scale diffluent ridge over the Atlantic, to the south-east of Greenland. There were depressions in the colder air to the west of the diffluent ridge and to the south-east of the confluent trough, while a ridge of high pressure extended from the warm air in the south-west across the baroclinic thermal pattern into the cold air in the north.

Expected development.—The region of greatest anticyclonic vorticity is marked A–A. The surface ridge is expected to swing so as to orientate itself along the line A–A and at the same time to move south-eastwards, broadside to the thermal flow. The depression in the west should swing to the left and deepen, that over Norway move rapidly north-east and the one over northern France move slowly south-east.

In Fig. 11 the chart for 0300 G.M.T., Saturday October 22, 1955 shows that these expectations would have been largely fulfilled.

Development of a new anticyclone.—The chart for 0300 G.M.T. on March 3, 1955 shown in Fig. 12 reveals the dominant surface feature to be a large anticyclone centred over Denmark. Over the central Atlantic is a weak ridge while a deep trough just east of Newfoundland is moving rapidly east. Ahead of this trough and over the ridge lies a well defined thermal diffluent-ridge confluent-trough pattern.

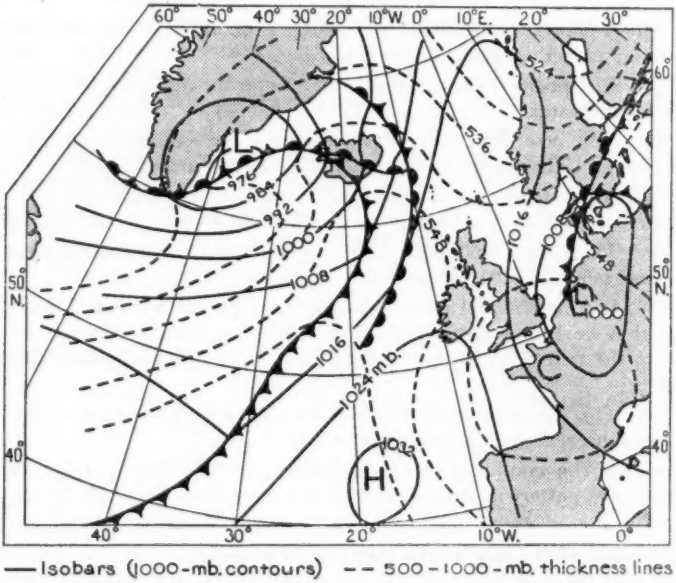


FIG. 11—CHART FOR OCTOBER 22, 1955 AT 0300 G.M.T.

Expected development.—The ridge should build and tend to orientate its axis more in the south-west to north-east direction. Since the ridge is in a different air mass from the anticyclone over Denmark it seems likely that large-scale ridging will lead to the formation of a new, detached, anticyclonic cell. While developing, this cell should move slowly east-south-east with the thermal wind across its centre.

In Fig. 13, the chart for March 4, 1955 shows that the expectations have been realized but that the diffluent-ridge confluent-trough pattern is no longer in existence, the confluent trough having become diffluent. Normally this should lead to the rapid destruction of the anticyclone. In the present instance, however, pressure rises have been so large that the consequent subsidence-warming has transformed the thermal pattern over the centre of the anticyclone into a barotropic region. Consequently an almost stationary, warm anticyclone results with depressions moving round it in the tight outer thermal gradient.

Filling of an advancing depression.—The large anticyclone, the formation of which was described in the previous paragraph, is shown in Fig. 14 to be still in existence on March 7, 1955. Its western lobe was at that time being approached by a depression to the east of Newfoundland. The thickness chart shows a small scale diffluent-ridge confluent-trough between this depression and the surface ridge.

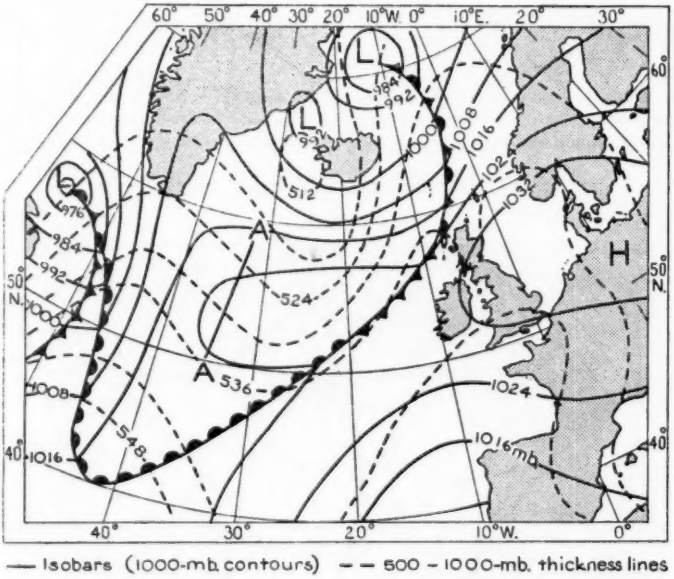
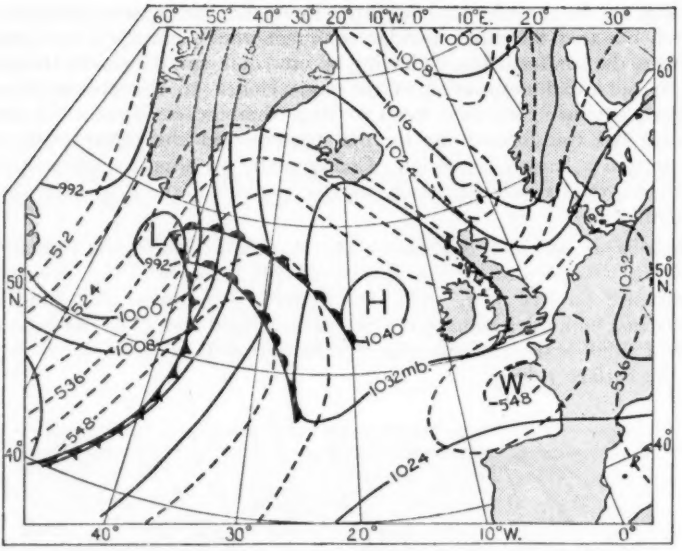


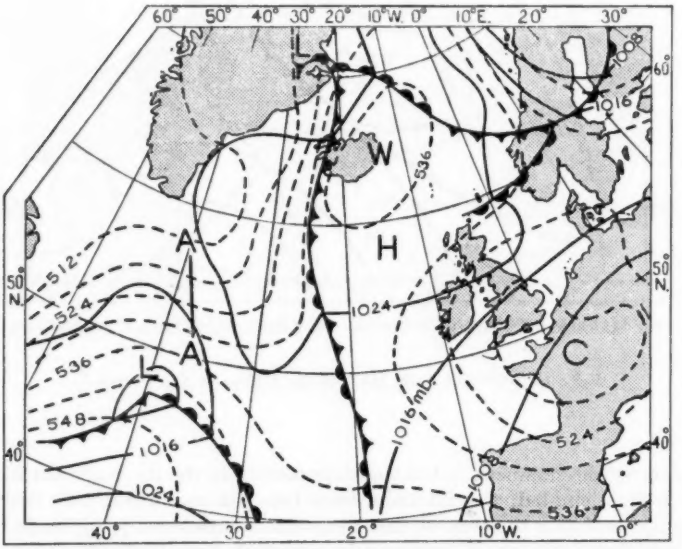
FIG. 12—CHART FOR MARCH 3, 1955 AT 0300 G.M.T.

Expected development.—Although the pattern in the thermal field is small it is well orientated, the thickness lines between confluence and diffluence lying almost along the west to east direction. Consequently, although heavy and prolonged pressure rises cannot be expected, definite development of the ridge should take place. The depression is on the warm side of the main baroclinic zone and so cannot well turn left. It must therefore fill up.



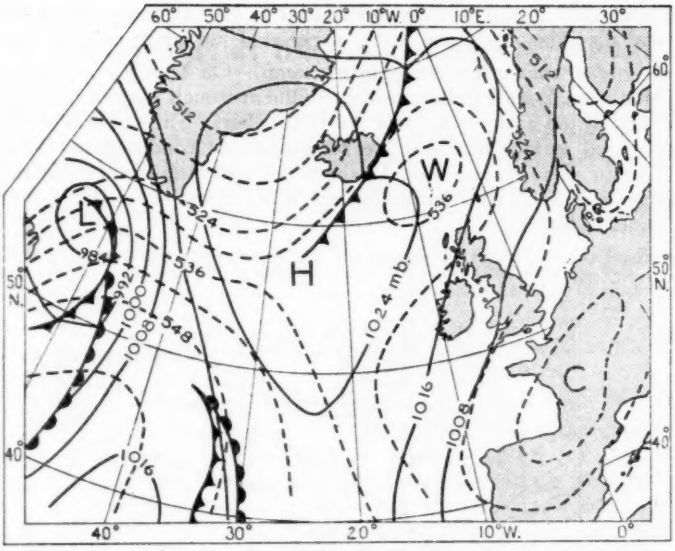
— Isobars (1000-mb. contours) -- 500-1000-mb. thickness lines

FIG. 13—CHART FOR MARCH 4, 1955 AT 0300 G.M.T.



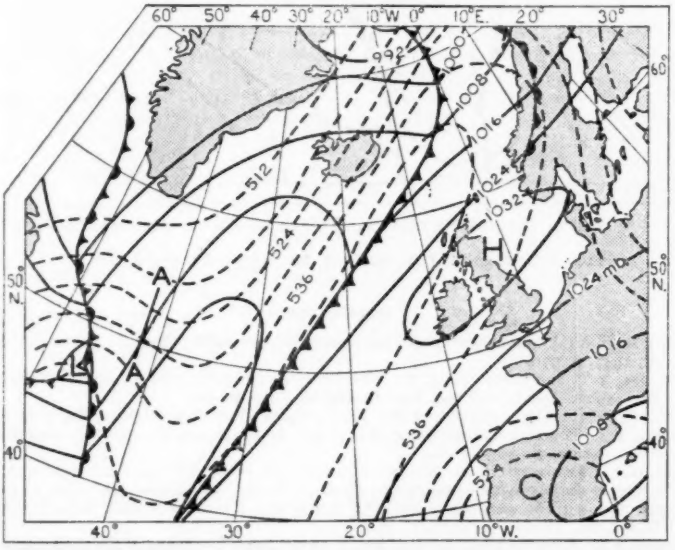
— Isobars (1000-mb. contours) -- 500 - 1000-mb. thickness lines

FIG. 14—CHART FOR MARCH 7, 1955 AT 0300 G.M.T.



— Isobars (1000-mb. contours) – – 500 – 1000-mb. thickness lines

FIG. 15—CHART FOR MARCH 8, 1955 AT 0300 G.M.T.



— Isobars (1000-mb. contours) – – 500 – 1000-mb. thickness lines

FIG. 16—CHART FOR MARCH 11, 1955 AT 0300 G.M.T.

The chart for March 8, 1955 reproduced in Fig. 15 shows the depression filled and the ridge developed at the expense of the larger ridge to the east.

Transfer of the main anticyclonic centre westwards.—On March 11, 1955, Fig. 16 shows that a small-scale diffluent-ridge confluent-trough pattern has appeared to the west of the anticyclone over the British Isles. The position of this and the associated surface situation are reminiscent of conditions on March 7, 1955. Again therefore we would expect the west-Atlantic surface ridge to strengthen and the nearby depression, which lies on the warm side of the baroclinic zone, to fill.

The final development is shown on the chart for 0300 G.M.T., March 12, 1955 in Fig. 17.

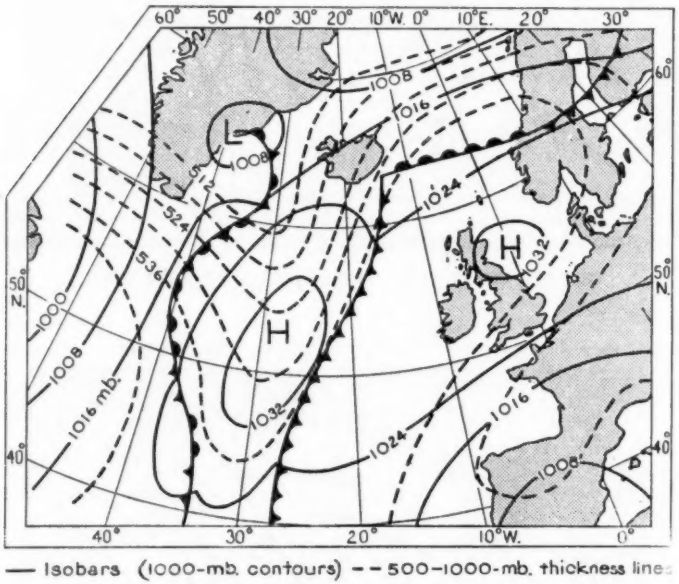


FIG. 17—CHART FOR MARCH 12, 1955 AT 0300 G.M.T.

REFERENCES

1. SUTCLIFFE, R. C.; A contribution to the problem of development. *Quart. J. R. met. Soc., London,* **73,** 1947, p. 370.
2. SUTCLIFFE, R. C. and FORSDYKE, A. G.; The theory and use of upper air thickness patterns in forecasting. *Quart. J. R. met. Soc., London,* **76,** 1950, p. 189.
3. SUTCLIFFE, R. C.; The formation of new anticyclones. *Met. Mag., London,* **82,** 1953, p. 163.
4. SAWYER, J. S.; Formation of secondary depressions in relation to the thickness pattern. *Met. Mag., London,* **79,** 1950, p. 1.
5. LAMB, H. H.; Two-way relationship between the snow or ice limit and 1000–500-mb. thicknesses in the overlying atmosphere. *Quart. J. R. met. Soc., London,* **81,** 1955, p. 172.
6. CRADDOCK, J. M.; The warming of arctic air masses over the eastern North Atlantic. *Quart. J. R. met. Soc., London,* **77,** 1951, p. 355.
7. SAWYER, J. S.; A preliminary classification of anticyclones by means of the thickness pattern. *Met. Mag., London,* **78,** 1949, p. 189.
8. SUMNER, E. J.; The significance of vertical stability in synoptic development. *Quart. J. R. met. Soc., London,* **76,** 1950, p. 384.

A SECOND REPORT ON FOG AT LONDON AIRPORT

By D. C. EVANS

Introduction.—Nearly seven years ago N. E. Davis[1] published a note on Fog at London Airport, based on the first four years of observations there. Ten years of observations are now available and a review of the preliminary appreciation has been made. As the diurnal variation of fog during the summer months is not a significant problem, only the months October to March are considered here.

Histograms of fog frequencies.—Hourly observations of visibility less than 1,100 yd. have been used to construct histograms in Fig. 1 which show, for each month, the distribution of four ranges of visibility hour by hour. The ranges of visibility are less than 220 yd., less than 440 yd., less than 880 yd. and less than 1,100 yd.

Copies of Fig. 1 are displayed in the forecast room at London Airport and are used by the forecasters when fog formation seems a probable development of the synoptic situation. Assessments are made of the fog point, the rate of cooling, the wind drift and other relevant factors, but the histograms give some indication of the probable range of visibility at certain times and help the forecaster to translate his general assessments into visibilities, times and probabilities, which, in spite of their wide margin of error, are of value to the operating companies. Similarly in forecasting the diurnal changes of visibility in fog or its dispersal these diagrams give a valuable summary of past experience.

Monthly totals.—Table I gives the monthly totals of hourly observations of visibility within the four ranges used in the construction of the histograms in Fig. 1. The corresponding percentage frequency is also given.

TABLE I—MONTHLY TOTAL OF HOURLY OBSERVATIONS OF VISIBILITY WITHIN CERTAIN RANGES

	Visibility							
	<220 yd.		<440 yd.		<880 yd.		<1,100 yd.	
	No. of hourly Obs.	Frequency	No. of hourly Obs.	Frequency	No. of hourly Obs.	Frequency	No. of hourly Obs.	Frequency
1946–55		%		%		%		%
October	298	4	408	5	689	9	858	12
November	424	6	568	8	880	12	1,020	14
December	418	6	555	7	845	11	986	13
1947–56								
January	340	5	464	6	720	10	861	12
February	127	2	219	3	496	7	620	9
March	169	2	251	3	523	7	673	9

Major periods with high frequency of fog.—The salient points in the variation of fog at London Airport, which were deduced from the first four years of observations by Davis, are fairly well confirmed by the additional data now available. The frequency and persistence of fog in November is not as outstanding as it was in the first four years but Table I confirms that

Percentage frequency of hourly observations
%
G.M.T.
December 1946-55
November 1946-55
October 1946-55
Number of hourly observations

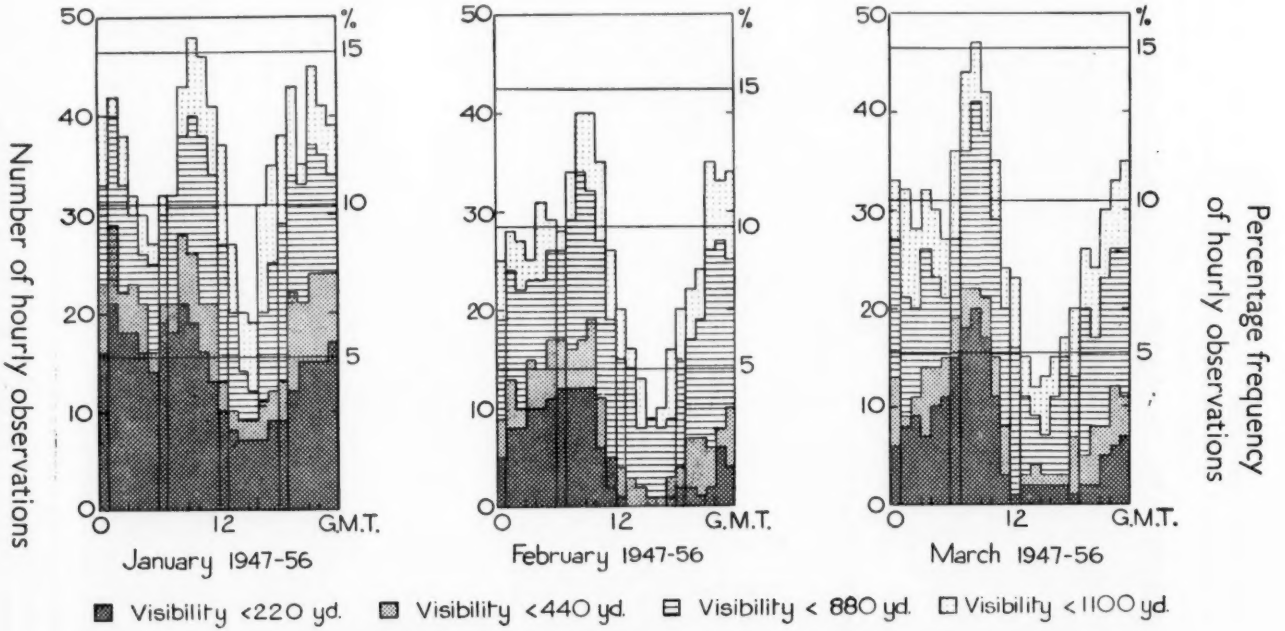


FIG. I—HISTOGRAMS OF FOG FREQUENCIES AT LONDON AIRPORT

November is the foggiest month although December is now shown to be only a little less foggy than November. The high frequency of fog on October mornings is confirmed. The highest frequency of the whole year occurs at 0700 and 0800 G.M.T. in October when the frequency of fog with visibility less than 220 yd. is over 10 per cent. and with visibility less than 1,100 yd. is over 20 per cent.

General pattern of diurnal variation.—It can now be assumed that the general structure of the diurnal variation of the frequency of fog in winter contains two maxima, one at about one hour after sunrise and another about midnight. The main minimum occurs about 1500 G.M.T., with a secondary minimum about 0500 G.M.T. It should be noted that on Sunday mornings the poorest visibilities occur an hour or more later than on week-days which suggests that local domestic smoke is a considerable factor in the thickening of morning fogs, the implication being that local domestic stoking takes place later on Sunday mornings than during the week.

Tendency for smoke fogs to disperse late in the evening.—In spite of the general deterioration of visibility from 1500 G.M.T. to midnight there is often a marked improvement between 2100 and 2200 G.M.T probably due to the decrease of local domestic smoke production. This improvement is partly obscured in the histograms in Fig. 1 by the onset of radiation fog at this time on other occasions, but it took place on about 50 per cent. of the occasions when the visibility at 2100 G.M.T. was between 330 and 1,100 yd. When the visibility at 2100 G.M.T. was less than 330 yd. an improvement within the next hour was observed on only 9 out of 44 occasions.

TABLE II—PERCENTAGE FREQUENCIES OF VISIBILITIES FOLLOWING ZERO HOUR FOR OCTOBER (0700 G.M.T.), FEBRUARY (0800 G.M.T.) AND MARCH (0700 G.M.T.)

Visibility<220 yd. at zero hour

Visibility	Hours after zero					
	1	2	3	4	5	6
yd.	*Percentage*					
<220	88	76	38	9	0	0
<440	91	79	59	24	6	3
<660	91	79	68	35	15	12
<880	97	82	71	41	21	12
<1,100	100	88	74	50	24	12

Clearance of thick fog during daylight.—One of the most critical problems connected with the diurnal variation of fog is the timing of an expected clearance of thick fog during the forenoon or early afternoon under the influence of purely diurnal changes. The following analysis was made to assess the degree of probability of various diurnal improvements in winter. Zero hour for improvement was taken as about one hour after sunrise and occasions with visibility less than 220 yd. at that hour were tabulated with regard to subsequent changes in visibility in Tables II and III. The winter months have been divided into two groups as the three months grouped together gave similar results.

No attempt has been made to exclude from these tables improvements which were not of a diurnal character. Assuming that only a small percentage of the improvements were due to changes in the synoptic situation, it is possible to

Map reference SX(20) 105836

Photograph by Dermott P. Fitzgerald

INN YARD AT CAMELFORD

(see p. 341)

[*To face p.* 336

Map reference SX(20) 115837

Photograph by Dermott P. Fitzgerald

TREGOODWELL BRIDGE FROM THE SOUTH-EAST BANK OF THE RIVER

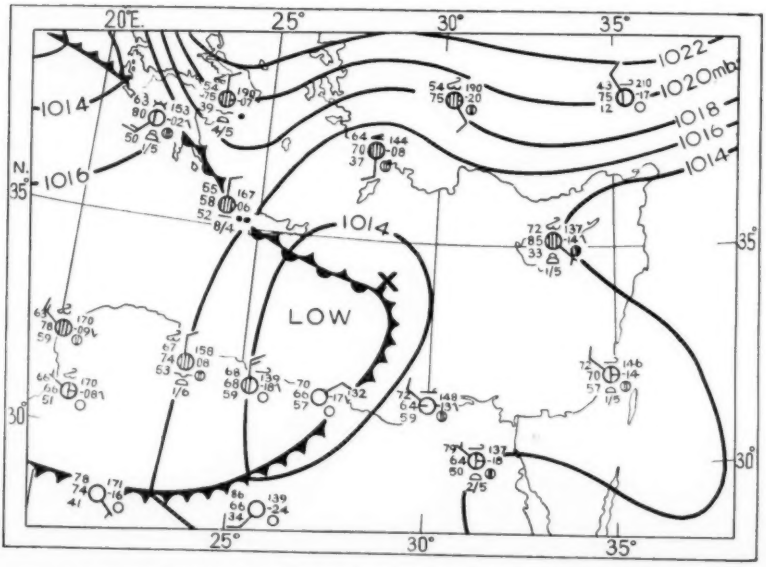
(see p. 342)

Map reference SX 201 115837 *Photograph by Dermott P. Fitzgerald*

TREGOODWELL BRIDGE FROM THE NORTH-WEST BANK OF THE RIVER

(see p. 342)

Photograph by T. A. M. Bradbury



CLOUD PATTERN AND 1200 G.M.T. CHART OVER THE MEDITERRANEAN

(see p. 347)

assess the probabilities of improvement from the above tables, on occasions when no change in the synoptic situation is expected. For example, if visibility is less than 220 yd. at 0900 G.M.T. on a morning in December there is more than a 50-per-cent. probability that the visibility will be less than 660 yd. at 1300 G.M.T.

The earlier improvement, relative to sunrise, of the low visibilities in Table III is attributed to the poorest visibility being associated with the initial lighting and stoking of domestic fires which, in midwinter, occurs earlier relative to sunrise.

Comparison of two four-year periods.—One of the most striking features of the four years previously examined was the high frequency of fog in November, but it will be seen in Table IV that in the next four years December had a frequency of fog which was almost as outstanding.

The increase of fog in December was partly due to the disastrous fog of December 5 to December 9, 1952, which accounted for 107 almost consecutive hourly observations, 77 of which were of visibilities less than 220 yd. However, if all these observations are subtracted from the 1950–53 totals, December still had more fog than November during this period.

TABLE III—PERCENTAGE FREQUENCIES OF VISIBILITIES FOLLOWING ZERO HOUR FOR NOVEMBER (0800 G.M.T.), DECEMBER (0900 G.M.T.) AND JANUARY (0900 G.M.T.)

Visibility <220 yd. at zero hour

Visibility	Hours after zero					
	1	2	3	4	5	6
yd.	*Percentage*					
<220	80	66	41	29	22	24
<440	85	76	54	39	37	34
<660	100	85	68	51	44	41
<880	100	93	76	68	56	44
<1,100	100	95	83	74	66	54

TABLE IV—TOTAL NUMBER OF HOURLY REPORTS OF VISIBILITY FOR PERIODS CONSIDERED

	1946–49	1950–53		1947–50	1951–54
	Number of observations			*Number of observations*	
October			January		
<220 yd.	122	135	<220 yd.	135	108
<1,100 yd.	395	380	<1,100 yd.	369	271
November			February		
<220 yd.	261	107	<220 yd.	68	59
<1,100 yd.	553	298	<1,100 yd.	345	254
December			March		
<220 yd.	141	221	<220 yd.	92	75
<1,100 yd.	370	496	<1,100 yd.	314	333

Some climatological means and fog frequencies.—Table V was prepared to illustrate the differing climatic conditions in the months of November and December in the two four-year periods considered above.

A fairly close correlation appears between the calms and the observations with visibility less than 1,100 yd. Mean temperatures, vapour pressures and wind directions do not show as much correlation with the frequency of fog as might be expected. The readings for December 1950 and December 1952 demonstrate these points as follows:—December 1950 and December 1952 are

similar in temperature and vapour pressure, which are both below average, but December 1952 had a higher percentage of calms which was paralleled by a higher percentage of fog. The larger percentage of easterly winds in December 1950 did not produce the larger number of occasions with thick smoke or fog which would be expected. This feature of calms being more significant than easterly winds in producing fog is further demonstrated by the figures for November and December 1953, which are similar under most headings but the much higher percentage of easterly winds in December is associated with only a relatively small increase in fog.

TABLE V—CLIMATIC CONDITIONS DURING PERIODS CONSIDERED

	Percentage of 3-hourly observations			Means of all 3-hourly observations		Percentage of hourly observations	
	Winds					Visibility	
	E'ly NNE.–SSE.	1–10 kt.	Calm	Vapour pressure	Dry-bulb temperature	<220 yd.	<1,100 yd.
				mb.	°F.		
1946–49							
November	18	56	13	9·3	45·5	9	19
December	25	57	10	7·9	41·7	5	13
1950–53							
November	21	50	10	9·0	44·9	4	10
December	20	58	17	7·8	40·3	8	17
1950							
December	29	66	10	6·2	34·9	1	10
1952							
December	8	53	23	6·8	37·3	15	23
1953							
November	11	51	21	10·0	47·3	7	16
1953							
December	31	68	31	9·8	45·7	9	19

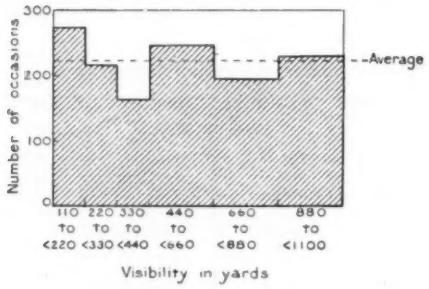


FIG. 2—HISTOGRAM OF FOG FREQUENCY AT LONDON AIRPORT DURING THE WINTER MONTHS OCTOBER 1950 TO MARCH 1956

There were 683 occasions with visibility less than 110 yd., but this column is omitted.
The pecked line is the average number of observations per 110-yd. step from 110 yd. upwards.
The totals for the 220-yd. steps have been halved to compensate for the doubled range of visibility.

Distinction between smoke and water fogs.—At Cardington, K. H. Stewart[2] found that visibilities in fog were almost invariably less than 200 yd. and that other visibilities within the fog range only occurred in the transitional stages of formation or dispersal. At London Airport there is a frequency of intermediate visibilities which cannot be only transitional but must be attributed to smoke pollution. It was thought that the range of visibilities

used in producing Fig. 1 might be large enough to obscure a lack of observations somewhere between 110 and 550 yd., therefore the occasions with fog during the winter months from October 1950 to March 1956 were divided into twice as many groups, using 110-yd. steps up to 440 yd. and then 220-yd. steps up to 1,100 yd. The total numbers of observations of visibility within each of these steps has been found and the histogram in Fig. 2 obtained. Apart from the visibilities less than 110 yd., all columns contain a fairly uniform number of occasions, though there is a noticeable minimum in the range 330–440 yd. This can be taken as the division between water fogs and smoke fogs, though bonfire and pyrotechnic smoke on Guy Fawkes night, November 5, 1954, was sufficient to reduce the visibility to 300 yd. Other occasions of visibility less than 440 yd. in smoke have been caused by very high concentrations of smoke which have built up over the metropolitan area and have subsequently been brought to the airport by the onset of a light easterly drift.

As the minimum visibility in smoke is near the minimum visibility at which many aircraft are operated, it is helpful to distinguish between thick smoke and water fog by using the term smoke and not fog when there are no water droplets present or expected. This distinction conveys to the recipient valuable information and can sometimes give confidence in what would otherwise be a discouraging situation.

Conclusion.—It is hoped that the above survey of fog at London Airport will be of use to forecasters in their daily forcasting work, and to the operating companies and others in their long-term schedule planning. It is thought that the ten-years' data now presented, are unlikely to be changed significantly by the accumulation of further data.

REFERENCES

1. DAVIS, N. E.; Fog at London Airport. *Met. Mag., London*, **80**, 1951, p. 9.
2. STEWART, K. H.; Radiation fog: investigations at Cardington, 1951–54. *Met. Res. Pap., London*, No. 912, 1955.

RAINFALL AT CAMELFORD, CORNWALL, ON JUNE 8, 1957

By A. BLEASDALE, B.A.

A very intense fall of rain, accompanied by unusually heavy hail, occurred at Camelford, Cornwall, on Saturday, June 8, 1957. This was the outstanding event amongst the widespread thunderstorms of the Whitsun weekend.

The largest amount of rain fell probably about a mile east by north of Camelford, over the drainage area of a tributary of the River Camel. The largest actual measurement was made at Camelford (Roughtor View) where the reading for the rainfall day was 7·09 in. At another rainfall station, Camelford (Advent), 1½ miles to the east, the amount measured was 6·33 in. The previous largest fall in a rainfall day known to have occurred in Cornwall was 4·53 in. at Liskeard (Penmilder) on October 5, 1929, though there have been falls of 9 in. or more on four known occasions in the nearby counties of Devonshire, Somerset and Dorset, and falls in the range from 6 in. to more than 8 in. on several occasions across the Bristol Channel in South Wales.

A full account of the rainfall and flooding has been received from Mr. C. H. Archer of Wootton Courtenay near Minehead, who visited the area twice to investigate the damage caused and search for evidence to amplify the data obtained from rainfall stations in the neighbourhood. Mr. Archer acknowledges his great debt to Mr. D. W. Bogle, Honorary Secretary of the Cornwall Rainfall Association, who made the measurement of 7·09 in. with his own rain-gauge at Camelford and had already, before the first visit, assembled much

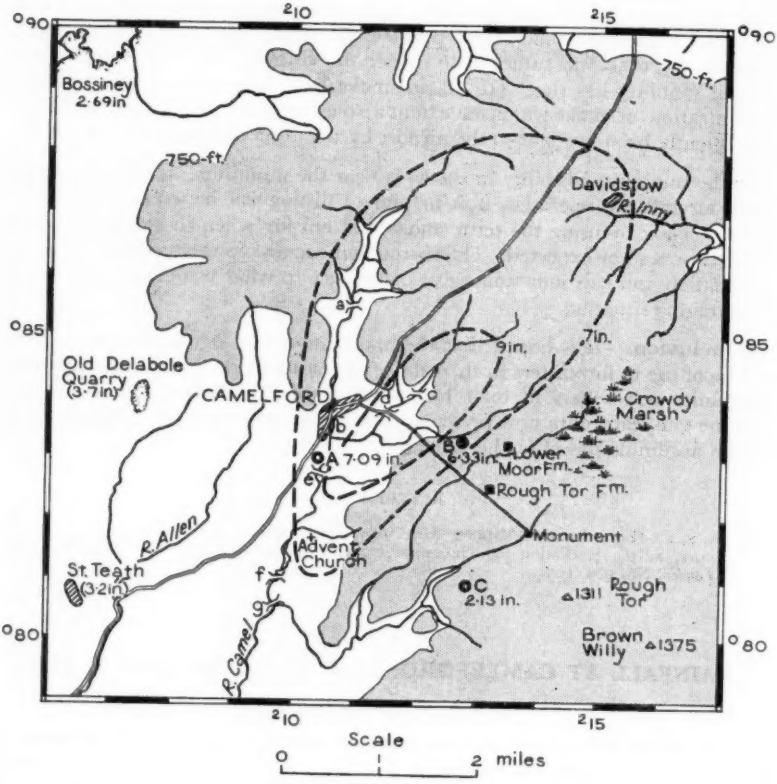


FIG. 1—RAINFALL DISTRIBUTION OVER THE CAMELFORD NEIGHBOURHOOD, JUNE 8, 1957

Rain-gauges.—A, Roughtor View; B, Advent; C, Stannon Clay Works. (Values as read, excluding hail)

Bridges.—

a, Slaughterbridge
b, Camelford Bridge
c, Tyland Bridge
d, Tregoodwell Bridge
e, Fonteroon Bridge
f, Kenningford Bridge
g, Trecarne Bridge

of the other information available. Discusions were also held with Mr. B. Pepper, Engineer, Cornwall River Board, and Mr. R. R. Haylett, Surveyor, Camelford Rural District Council, who were directly interested, in their official capacities, in the effects of the rainfall. This note is intended to provide only a brief review of some of the main conclusions of Mr. Archer's account. Copies of the full report are available from the author.

Before dealing with the areal distribution of the rain, the report discusses the evidence regarding the timing of the fall and the severity of the hail. At Camelford several separate measurements were made with the rain-gauge and these showed that the greater part of the rain, 5·43 in., fell within 2½ hr. from 1230 to 1500 G.M.T. Though there were 10 separate measurements within this period there seems no doubt, from all accounts of the rainfall and flooding, that more than half of the amount fell during the first hour. The exceptionally high intensity thus indicated is nevertheless an underestimate since it was also during this first hour that the heavy showers of hail occurred and little of this was measured by the rain-gauge. It was unfortunately difficult to form any accurate estimate of the amount of hail. The total duration of the showers, which included hailstones up to the size of large peas, was "variously estimated at from twenty minutes to an hour". Mr. Bogle, inspecting his rain-gauge after a very heavy shower for fear that the funnel would be choked, found that very little hail had been retained. There was other evidence that hailstones bounced 3 ft. in height and more than 12 ft. horizontally. On the other hand, there was no possibility of estimating the average depth of hail on the ground, as masses of hailstones, some of them congealed into large blocks, were washed about by the flood waters. The photograph facing p. 336 shows the result in one place in Camelford, the inn yard, where the hail was piled almost knee-deep.

Mr. Archer's estimate is that very nearly an inch of equivalent rain may have been lost from the rain-gauge measurement during the hail showers. Though, in the circumstances, the actual amount is speculative, the estimate does not seem to be a gross exaggeration. Mr. Archer's conclusions are, first that the fall at Camelford in one hour from 1230 to 1330 G.M.T. must have reached approximately 4 in., including the hail; and secondly that the fall for the rainfall day at Camelford must have reached 8 in.

A fall of 4 in. in one hour is not known to have been actually measured in Britain. The value which has been accepted as the largest amount yet measured within this time was 3·63 in. at Maidenhead (Lowood) on July 12, 1901, though the original Report in *British Rainfall* 1901 used the phrase "in little more than an hour". On June 26, 1953, 3·54 in. fell in 55 min. at Eskdalemuir Observatory, an amount which included 3·15 in. in 30 min., details of the fall being available from the chart of the rain recorder. A further example, more directly relevant to the Camelford estimate, is provided by the observations from Hewenden Reservoir, Bradford Waterworks, for June 11, 1956, where a fall of 6·09 in. within 1 hr. 45 min. was measured; on this occasion at least 3·48 in. must have fallen within one hour and unless the rainfall intensity was remarkably uniform over the full period, it is probable that 4 in. or even a little more fell within an hour. At Camelford, whether the estimate of 1 in. for the hail is fully or only partially accepted, the midday fall was probably very close to the greatest hourly intensities yet known or estimated for this country.

With regard to the second condusion, Mr. Archer uses the estimate of 8 in. for the rainfall day at Camelford in conjunction with other data and his survey of the ground, in order to draw a map of the rainfall distribution. This map has been used as the basis for Fig. 1 which reproduces the 9-in. and 7-in. isohyets as drawn on the original. The 3-in. isohyet, which is not shown, enclosed most of the ground covered by Fig. 1 except for areas of a few square miles in the north-west and south-east corners. There are three main points of interest. It is estimated that the fall to the east of Camelford must have exceeded 9 in. over an area of more than 1 square mile; this area lies almost entirely within the drainage basin of the small tributary flowing into the Camel about a third of a mile down-stream of Camelford Bridge (b). Secondly, the rainfall gradient to the south-east of this area must have been extraordinarily steep; the readings of 6·33 in. at the Advent rain-gauge (B in Fig. 1) and 2·13 in. at Stannon Clay Works (C) indicated a gradient of 4·2 in. in little more than 2,000 yd.; the rapid decrease of erosion along the road leading south-east to the monument at NGR SX(20)138817 was among the features which strongly reinforced this evidence and suggested a large decrease in rainfall in the first 300 yd. south-east of the Advent gauge, so that the 3-in. isohyet must have been very close to the 7-in. isohyet in this direction. Finally, in the relatively broad area to the north-east of Camelford in the upper Camel valley, shown as receiving upwards of 7 in. of rain, the timing of the rainfall was very different from that in Camelford; the fall was less intense but more prolonged and reached its greatest intensity between 1700 and 1800 G.M.T. in what must have been in some respects a separate fall.

The description of the flooding which occurred is closely linked with these three characteristics of the rainfall distribution. The four bridges marked c, d, e and f in Fig. 1 were either destroyed or damaged. The photographs between pp. 336–337 show two views taken from opposite directions of Tregoodwell bridge at d after the main flood had subsided. Though the bridge was still passable the damage was severe—"one of its main members, a rectangular granite block measuring 9 ft. by 3 ft. by 1 ft. was lifted up, torn from its railing, and hurled transversely across the stream". But the bridges at a and b were not damaged, as the flood from the upper Camel valley was much less violent. Trecarne bridge at g and others down-stream of this point were also not damaged. The very rapid decrease of rainfall to the south-east was further confirmed by the lack of significant flooding in the tributary which joins the Camel at Trecarne after flowing past Devil's Jump. At Camelford there were two floods separated by about 3½ hr. The first was due to the intense rain at midday in Camelford and the near neighbourhood. It reached its peak within an hour and this was followed after 1330 G.M.T. by a substantial fall. During this flood, water flowing down the main road from the north-west, with a depth of 3 to 6 in. right across the road, flowed over Camelford bridge and into the houses beyond. The second flood came down the River Camel from the upper valley, with a peak corresponding to the maximum rainfall intensity between 1700 and 1800 G.M.T. in that area.

The report contains much other interesting information, including a comparison with the rainfall at Cannington, Somerset, of August 18, 1924, to which the Camelford fall bears a close resemblance with respect to the areas covered, the maximum measured or estimated falls, and peak intensities.

There is also a discussion of previous floods at Camelford, in particular that of August 30, 1950, which was much more serious than the 1957 flood though the rainfall was very much less and did not give rise to any measured fall of as much as 2 in. The conclusion reached is that if the location of the heaviest rainfall on June 8, 1957, had been displaced by only 1 to 2 miles to the north-west or north, the damage in Camelford itself would have been disastrous and might have been accompanied by serious casualties or loss of life. It is stated that improvement works are already in hand to give greater protection against future floods in this valley.

CHARLES SUMNER DURST, O.B.E., B.A.

Mr. Durst retired on September 6, 1957, after 38 years' service in the Meteorological Office.

After graduating in mathematics at Pembroke College, Cambridge, in 1910, Mr. Durst spent several years in the Malay States as a Surveyor and during the First World War was commissioned in the Royal Engineers and served in Gallipoli, Palestine and the Western Desert. After demobilization in 1919 Mr. Durst turned his attention to meteorology and entered the Office as a Junior Professional Assistant. A few months later he was promoted and joined M.O.1 under the late Commander Brooke-Smith who was then the Marine Superintendent. Mr. Durst remained in M.O.1 for seven years and during that time played a major part in the introduction of the punched card system for the analysis of meteorological statistics and also wrote a study on *The doldrums of the Atlantic* which was published as *Geophysical Memoirs* No. 28.

From 1928 to 1932 Mr. Durst was one of the group of meteorologists who carried out a massive programme of experiments at the Royal Airship Works, Cardington, on the structure of wind in the lowest two hundred feet or so of the atmosphere. The results of these experiments are contained in *Geophysical Memoirs* No. 54 which is still regarded as a mine of fundamental data on atmospheric turbulence. A separate section of this Memoir is devoted to a presentation of a theory of eddies which Mr. Durst developed during the progress of the work at Cardington.

From Cardington Mr. Durst was posted to headquarters and until 1940 served in the Forecast Division. The 1930's saw much pioneer work in the development of Empire Air Routes and many of the famous aviators of those days had occasion to draw upon Mr. Durst's extensive knowledge of world meteorology.

The outbreak of the Second World War in 1939 laid heavy requirements upon the Meteorological Office and among them was a need expressed by military planners for climatological appreciations covering many areas of the world and written from the aviation standpoint. In 1940 therefore Mr. Durst took charge of a new branch for Special Investigations, and in that capacity he was frequently consulted by such bodies as the Chiefs of Staff Committee. With his assignment to Special Investigations full scope was given Mr. Durst to exploit his scientific ability in the application of meteorological data to a wide variety of problems. There followed and has continued a steady output of papers on such diverse topics as the variation of wind with time and distance, the meteorology of airfields, the accuracy of route-wind forecasts for aviation,

the calculation of geostrophic trajectories, the importance of jet streams to air navigation, surface friction and turbulence in the ocean, pressure changes and the efflux of gas in mines—to give just a selection. In the re-organization of the Meteorological Office in 1948 Mr. Durst's post was upgraded and he was appointed Assistant Director (Special Investigations). He retired from this post in October 1953, but remained in the Office a further four years and was able to complete a number of investigations as well as to launch out on some new ones.

It is pleasant to recall as milestones in a career of such distinction that Mr. Durst's merits have received public recognition several times. In 1937 he was awarded the Buchan Prize of the Royal Meteorological Society; in 1946 he was made an Officer in the Civil Division of the Order of the British Empire; in 1949 he was awarded the Groves Memorial Prize for Meteorology by the Air Ministry; in 1950, and again in 1956, he was awarded the Bronze Medal of the Institute of Navigation.

Mr. Durst's career in meteorology has spanned nearly four decades and almost throughout that time he has been in the front rank of meteorologists and has retained a freshness and originality of thought that many would be glad to possess for a short period at the height of their powers. Retirement is a term which seems only remotely applicable to Mr. Durst and indeed he fully intends to continue his studies into the many meteorological problems of air navigation. Both in his own work and in the inspiration he has given to others Mr. Durst has made a host of friends who will wish him many years of happiness in which leisure may gradually attain precedence over meteorology.

NOTES AND NEWS

Meteorological Magazine: increase in price

We regret that owing to further increases in the cost of printing and publication it has become necessary to again raise the price of the *Meteorological Magazine*. The price will be 2*s*. 6*d*. an issue with effect from the January 1958 number. The net annual subscription will become 32*s*. including postage. Present subscribers will remain on the existing rate until renewal of their subscriptions is due.

Some remarks on lightning flashes and ball lightning

A number of scientists (G. C. Simpson, C. T. R. Wilson, W. Findeisen, J. Küttner etc.) have studied the electrification of thunderclouds and arrived at important conclusions concerning the distribution of positively and negatively charged parts of the thunderclouds. Their figures show more or less regular patterns of positive and negative signs throughout the cloud. I refer to Schonland's book "The flight of thunderbolts"[1] and Hann-Süring's "Lehrbuch der Meteorologie"[2]. All investigators agree that the primary thunderstorm condition is unstable warm air rising upward with great speed. In the up-draughts the raindrops are charged with electricity in different ways to an amount that is "quite enough to account for all lightning from the thundercloud and for other less spectacular electrical effects as well" (Schonland,[1] p. 122).

There is, however, one important effect I should like to emphasize: what happens in the tremendous down-draught process when the up-draught comes to an end so that all the rain and hail particles gathered up to great heights

must fall down? The fact is illustrated by Schonland[1] in his figure 27C and he adds: "At the present time nothing is known with certainty as to the electrical conditions in the down-draught region" (p. 133). Yet we must consider that this down-draught represents a state of instability surpassing to an extremely high degree that of the up-draught before. The temperature in the region where hail and heavy rain are falling out is much lower than that of the surroundings and the downward-directed air streams must reach enormous speeds.

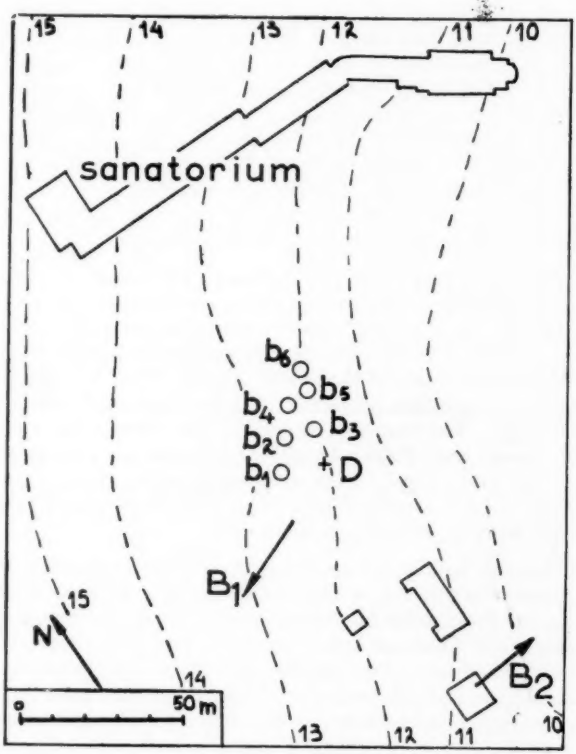


FIG. 1—PLAN OF THE NETHERLANDS STUDENTS' HEALTH RESORT AT LAREN

Fig. 1, taken from my article on the event in *Hemel en Dampkring*[3], shows the plan of the sanatorium grounds. The broken lines are contours of height in metres. The cross D shows where Mr. Dik was standing and B_1 the direction in which he saw the ball move. B_2 shows the direction in which Mev. Van Erp saw another ball explode. The oaks b_1 and b_2 were struck by lightning. b_3 and b_4 are also oaks and b_5 and b_6 are acacias.

Moreover thousands and thousands of tons of hail and water come down in a short time. All these effects are well known. The electricity-generating processes must increase during the fall up to amounts considerably higher than during the up-draught. I dare to presume that the principal electrical activity must be found in this second part of the thunderstorm phenomenon. Here the

friction of ice and water particles (Sohncke, Küttner) and especially the "waterfall" electricity (Lenard, Simpson) must be extremely important. With regard to Lenard's phenomenon I should like to point to a possible effect. A large drop falling down will tend to break up. When break-up occurs, the small drops falling with less speed must be captured by the following large drops. Then these drops will also break up and so on. There must occur a chain process of collisions with a rapid increase in the number of electrically charged particles. In a short time interval a lightning flash must follow. Both Schonland[1] (p. 127) and Süring[2] (p. 1006) discuss the well-known effect of a flash preceding the rain and both consider the rainfall to arise from the action of the lightning flash. Schonland suggests the raindrops were supported by an electric field destroyed by the flash so that the rain falls out of the cloud following this "cutting of the strings of the electric parachute", as Schonland puts it. The above sketched development of electricity may point to the contrary action: the rain produces the flash. Indeed the flash will be seen at the same moment that it has taken place, and the thunder follows immediately, but the rain needs some time to come down and therefore the observer does not realize that nevertheless the rain has been the cause of the flash.

Concerning the occurrence of ball lightning, Schonland doubts its reality. He refers to an investigation by the American meteorologist W. J. Humphreys. I am sure that by far the most meteorologists disagree with this view. The observations of ball lightning all over the world show a good many common features. They are not caused by optical illusion. They are not observed by men "hardly in a position to give a reliable account of what happened" (Schonland p. 51). The numerous records in the Netherlands and elsewhere have by no means been "given by observers involved in thunderstorms on high mountains like the Alps". "The stories of fire-balls passing down chimneys and bouncing round the house with a sulphurous smell must be treated"—in all seriousness and then reveal their reality.

As to the cause of ball lightning we may accept that at the high temperature of the electrical discharge a number of chemical actions occur forming, as suggested many years ago by Th. Neugebauer, a mixture of electrically positive and negative gases. Dust and smoke particles, soot, and water droplets may take part in the process. This mixture is stable at the high temperatures concerned. When the ball cools the chemical balance may change either gradually or rapidly. In the first case this balance is maintained and the ball disappears noiselessly; in the second case, however, the mixture becomes unstable.

I had the good opportunity to verify the reports of two observations of ball lightning occuring just after one very near lightning flash, striking two trees and damaging the telephone cables in the grounds of the Netherlands Students' Health Resort at Laren near Hilversum, October 25, 1956 at 20hr. 15 min. Fig. 1 is a plan of the grounds. Mr. Dik, Chief of the Technical Department, did not see the flash because he was looking in another direction but he saw a large ball moving away from the trees and exploding at some distance. Mev. Vann Erp also did not see the flash but observed outside her house a ball appearing and exploding. Both observations were quite independent and related to two different fire-balls. The inhabitants of the resort heard a rather long clap of thunder and some of them were surprised when they heard that the

strike was at no greater distance than about 80 metres. In fact there were three thunder claps caused by the close flash itself and the two exploding balls, with an appreciable time difference.

Mr. Dik did not see the flash, and he did not even hear the thunder. Only the following morning he realized that he had been at a distance of only 14 metres from the trees which had been struck!

The fact is known. Schonland mentions it but he is inclined to doubt it and to think "that in such cases the sound it too weak in intensity to be noticed in the general upset caused by a near discharge. Weak thunder of a special type is to be expected from such discharges, since they often consist entirely of a series of flickering tongues or streamers, each moving forward a little farther than its predecessor, and since they are not followed by the rapid and brilliant, and noisy return discharge which produces the characteristic whip-like crack of a flash to ground". This brilliant and noisy part of the flash was without doubt present in the Laren case! Mr. Dik did not give the impression of having been panic-stricken at the moment of the discharge in his immediate neighbourhood. I shall be glad to receive reports of other reliable observations of the same character.

S. W. VISSER

REFERENCES

1. SCHONLAND, B. F. J.; The flight of thunderbolts. Oxford, 1950.
2. HANN-SÜRING (newly written 5th edition by SÜRING, R.); Lehrbuch der Meteorologie. Part 9. Leipzig, 1951.
3. VISSER, S. W.; Twee bliksemballen bij Laren (N.H.). *Hemel en Dampk.* **55**, 1957, p. 45

Rainfall at Christmas Island (1°57′N. 157°27′W.)

A notable feature of the rainfall at Christmas Island is its extreme variability. In 1905 the annual rainfall was 298 in. whereas in 1917 only 10 in. was recorded. During the five and a half months from October 15, 1956 when the Meteorological Office station was opened, to March 18, 1957 the total rainfall was only 0·87 in. and then, in just over two hours on March 29, 1·82 in. fell. Another heavy fall occurred on April 3. Although at the official recording station there was only 1·05 in. between 9 a.m. and 9 p.m., at the airfield four miles away the rain was very much heavier, an unconfirmed report giving 12 in. during the day. Half an empty oil drum, cut off to form a cylindrical vessel about 12 in. deep, had been cleaned out and left in the open at 8 a.m. and by 5 p.m. was seen to be overflowing. Close questioning of the "observer" left little doubt that there had been a genuine rainfall of 12 in. in about nine hours. Certainly the flooding which occurred at the airfield was very much worse than that at the meteorological office site. Such high rates of rainfall, though for shorter periods, have been confirmed by the readings of the official rain-gauge. On May 26, 1957, 2·82 in. fell in 2 hours 10 minutes, the great bulk occurring in a period of 1 hour 24 minutes during which the average rate was probably about 1·8 in. per hour. On this occasion the airfield had much less rain.

M. H. FREEMAN

Cloud Pattern over the Mediterranean

Details of the photograph (facing p. 337) are as follows: date, March 26, 1957; time, 1010 G.M.T.; position, 34°10′N. 28°30′E. (shown by cross on chart facing

p. 337); height, 41,500 feet, indicated on a QFF setting of 1013 mb.; direction of view was south-south-east. It was taken from the rear window of a Transport Command Comet.

The cloud is stratocumulus, probably at a height below 5,000 feet. This is indicated by the shadows visible on the sea in the right-hand lower part of the print. The interesting feature is the way the cloud pattern suggests cyclonic circulation. The 1200 G.M.T. chart on that day indicates that a depression was in fact centred near this position. The centre of the circulation at cloud level may well be some distance from the surface centre, which in this case could not be accurately located.

Previous history showed that a cold front had crossed the Malta area the previous day. This front had since travelled very rapidly eastwards. Marked subsidence of the cold air had made the front very weak indeed in the region south of the centre, and no convective clouds were seen over the sea.

Two distinct bands of cloud were observed from the air, both were narrow and were spaced about a hundred miles apart. The photograph shows the most easterly band.

This area had been crossed at 0910 G.M.T. on a parallel track a little further south, and at that time the stratocumulus had a fan-shaped pattern, with the wider arc of the fan facing roughly south-east. There was no other low cloud within 50 miles of the area photographed, but an extensive cover of cirrostratus extended over the greater part of the Eastern and Central Mediterranean.

T. A. M. BRADBURY

REVIEW

Année Géophysique Internationale. International Geophysical Year. 1957–1958. OMM/WMO—No. 58. AGI/IGY 2. 24 mm. × 16 mm. World Meteorological Organization, Geneva, 1957. Price: Sw. fr. 8.

This publication has been prepared by the World Meteorological Organization to enable all concerned to ascertain which meteorological stations will be making observations of any type during the International Geophysical Year. Stations are listed under the eight headings, surface synoptic observations, upper air, radiation, atmospheric ozone, atmospheric electricity, sferics, nuclear radiation and atmospheric chemistry. Over 2,000 stations are listed under the first category and 650 under the second. Details of the type of instrument used are stated for upper air, radiation and ozone stations.

The booklet, compiled with the clarity and ease of reference always associated with W.M.O. publications, will be indispensable to all users of the observations made during the Year.

G. A. BULL

OFFICIAL PUBLICATION

The following publication has recently been issued:—

Annual Report on the Meteorological Office. April 1, 1956–*March* 31, 1957.

This Report is an account of the year's activities of the Meteorological Office as the State Meteorological Service. The new features introduced last year, cover design and illustrations and presentation mainly in the continuous narrative form, have been continued.

The provision of meteorological services for the general public, for aviation and shipping, for agriculture, industry, commerce and public utilities has continued to develop. The provision in the London area of an automatic dialling telephone service for the issue of forecasts to the public was, in collaboration with the General Post Office, extended during the year to Liverpool, Manchester, Birmingham, Glasgow, Belfast and Cardiff. Much consideration was given to the possibility of using mechanical and electronic methods for the recording and processing of meteorological data both for the improvement of information services and for meteorological research. The preparation of forecasts both for the general public and transatlantic air routes has been aided by the introduction of a direct teleprinter link on the transatlantic cable between this country and Canada; this ensures the prompt and regular reception of meteorological reports from North America and has eliminated the difficulties formerly caused by radio fade outs.

Much effort was devoted on the research side to numerical forecasting whereby forecast pressure maps are produced by calculation. An electronic computer, primarily for this work but also for other problems involving complex calculations is expected to be installed by the end of this year. Work continued on a series of controlled trials on the possibility of inducing rain artificially. The Meteorological Research Flight has continued its high altitude research which has a special significance in view of the increasing heights at which aircraft operate.

During the year under review the decision was taken to unite the Headquarters divisions now situated in London, Dunstable and Harrow at a new headquarters at Bracknell, Berkshire.

METEOROLOGICAL OFFICE NEWS

Retirements.—*Mr. C. A. Jupp*, Experimental Officer, retired on September 13, 1957. After service in the First World War from 1916 to 1919 and later for six years in the Royal Air Force, he joined the Office in July 1927 and spent his first five years at aviation outstations. Since 1932, apart from a period between 1945–1948, he has served successively in the Forecast, Marine and General Services Divisions.

Mr. H. A. Curtis, Senior Assistant (Scientific) retired on September 30, 1957. He served in the First World War from 1916 to 1919 and joined the Office from the Air Ministry in March 1929. He was posted to Croydon Airport. In 1935 he was transferred to the Forecast Division at Headquarters and since 1939, until his retirement, he has served continuously in the London Forecast Office. He was awarded the British Empire Medal in the New Year's Honours List of 1955. Mr. Curtis has accepted a temporary appointment in the Meteorological Office.

Academic successes.—The following members of the staff have been successful in recent examinations. We offer them our congratulations.

B.Sc. (General): J. D. Perry, P. J. Wiggett.

B.Sc. (Special): R. Baker, P. Menmuir (2nd Class Honours).

General Certificate of Education (Advanced Level): A. R. Belton, B. A. Cope, M. F. Gaskin, R. P. Healey, D. E. Lantry, Miss M. J. Llewelyn, Miss E. M. Walsh, D. Y. Warne.

Higher National Certificate: A. McEwen.

WEATHER OF SEPTEMBER 1957

In the British Isles the synoptic situation was changeable throughout the month with any particular pattern rarely persisting for more than a few days.

The month opened with fine sunny weather in Scotland and the north of England, but in the south it was changeable with periods of rain. Troughs, associated with a deep depression near Iceland, gave widespread rain on the 4th as they moved eastward across the country. Another depression deepened off the west of Scotland on the night of the 5th–6th and the following day was generally wet with heavy local rain and gales over the north-western part of the country. The 8th was sunny and dry apart from a few scattered showers, chiefly in Scotland, but weather was generally unsettled during the following week. A slow-moving frontal system, followed closely by a wave depression on a trailing cold front, reached western Ireland from the Atlantic late on the 8th and rain became widespread and locally heavy on the 9th and 10th. Pressure remained low over southern Scandinavia during the next five days; from the 11th to 13th there was rain in most parts of the British Isles with scattered thunderstorms and strong winds which reached gale force locally in northern districts. Gales and squally showers continued in the north of Scotland throughout the 14th and 15th, but further south the weather slowly improved. The next three days were mostly fine in the south and Midlands but still rather changeable in the north. Temperatures were somewhat below the average until the 18th when they rose to the upper sixties in the south of England and reached 70°F. at Mildenhall. Generally dull wet weather returned on the 20th, with a broad frontal belt lying roughly east to west across the country, and persisted for several days. An intense depression, the remains of an old tropical storm, arrived off south-west Ireland on the 23rd and in its circulation a broad area of rain spread northwards across England and Wales into Northern Ireland. The rain was heavy in places and thunderstorms developed over East Anglia and the Midlands; during one of these storms a miniature tornado occurred over Lincolnshire. Meanwhile colder air, preceded by outbreaks of rain, was spreading southwards from Scotland and by the 24th had reached the Midlands and the London area; the maximum temperature on that day was only 50°F. in North Wales, contrasting sharply with a south-coast maximum of 70°F. An anticyclone in the eastern Atlantic increased in intensity on the 26th and 27th and the following day cold air spread south-east over the whole country bringing mainly bright and showery conditions for the remainder of the month. Slight air frost occurred in a few places early on the 30th.

Temperatures were generally below normal in all parts of the country with day maxima 2–3°F. below the September average. Sunshine totals were deficient for most parts of the country some places having only about half their normal September amount. Rainfall was 198 per cent of the average in England and Wales but only 98 per cent in Scotland. More than twice the average was recorded over most of Wales and much of England north of the Thames, except in the north-east. Three times the average was exceeded in Nottingham.

The rain delayed harvesting and in some areas it has been estimated that as much as half the crops have been lost. Toward the end of the month, flood water following heavy rain caused even greater chaos especially in the Midlands

where fields became unworkable and autumn ploughing was brought practically to a standstill. Potato blight caused serious losses as also did "virus yellows" in sugar beet which followed heavy aphis infection earlier in the year. Flower crops suffered in the wet weather, but grass and green vegetables continued to be healthy and plentiful.

Over most of the northern hemisphere the circulation was decidedly weaker than normal. The Indian monsoon appeared to have ended early and this also applied to the summer-time extension of the monsoonal low pressure towards north-east Asia. Pressure anomalies were positive over more or less all Asia, actually from Ceylon to beyond the North Pole in Greenland and Alaska: the anomaly reached +5 mb. in central Asia and at Spitsbergen. Pressure was 5 to 7 mb. above normal in Iceland. The subpolar low-pressure belt was displaced south in all sectors, but most in the Atlantic–European sector where pressure was lowest over south Norway and Sweden (1005 mb., greatest anomaly −9 mb.) instead of in the usual trough from south-west Greenland to Bear Island. There were smaller negative anomalies over northern Canada in another low-pressure cell displaced well to the west.

The lowest pressures in the Atlantic sector were actually several millibars above the usual minimum for September. The Azores high-pressure belt was also weaker than usual (highest monthly mean pressure 1020 mb., about 2 mb. below the usual maximum pressure) and several degrees south of the normal position except in the Bay of Biscay. Mean pressure gradients were weaker than usual except in two regions: over the Canadian Prairies and near the British Isles, where the month was notably windy. There was also a pronounced gradient for northerly winds in the Norwegian Sea.

The Rocky Mountains region was 2 to 3°C. warmer than normal and in a narrow zone over the Prairies the mainstream of the circulation appears to have been somewhat north of normal with pronounced north-westerly gradient winds. Above-normal temperatures were also noted over most of the Atlantic seaboard of North America (anomaly +4°C. over southern Baffin Land) and over a broad belt from the Red Sea to north-west Siberia and north Russia (anomalies up to +3°C. in several areas). The month was notably cool over most of the United States of America, Europe and east Asia (anomalies reaching −3°C. locally in each region named).

Rainfall exceeded twice the normal September totals at many places in north-west and central Europe and was locally over three times the normal. With the early cessation of the monsoon most of India was notably dry.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	73	29	−1·8	195	+5	85
Scotland	69	23	−2·0	99	+2	105
Northern Ireland ...	67	31	−1·2	170	+5	90

RAINFALL OF SEPTEMBER 1957

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ...	2·48	136	*Glam.*	Cardiff, Penylan ...	5·07	166
Kent	Dover	3·35	145	*Pemb.*	Haverfordwest ...	8·70	245
,,	Edenbridge, Falconhurst	3·16	139	*Radnor*	Tyrmynydd	11·27	292
Sussex	Compton, Compton Ho.	3·85	138	*Mont.*	Lake Vyrnwy	9·30	258
,,	Worthing, Beach Ho. Pk.	3·13	146	*Mer.*	Blaenau Festiniog ...	14·69	186
Hants.	St. Catherine's L'thouse	4·16	174	,,	Aberdovey	8·72	273
,,	Southampton (East Pk.)	2·65	122	*Carn.*	Llandudno	5·57	262
,,	South Farnborough ...	2·88	151	*Angl.*	Llanerchymedd ...	6·83	232
Herts.	Harpenden, Rothamsted	3·07	157	*I. Man*	Douglas, Borough Cem.	6·38	195
Bucks.	Slough, Upton	2·52	143	*Wigtown*	Newton Stewart ...	4·51	132
Oxford	Oxford, Radcliffe ...	3·99	233	*Dumf.*	Dumfries, Crichton R.I.	3·78	139
N'hants.	Wellingboro' Swanspool	4·42	246	,,	Eskdalemuir Obsy. ...	4·27	115
Essex	Southend, W. W. ...	2·62	158	*Roxb.*	Crailing...	2·04	100
Suffolk	Felixstowe	2·45	148	*Peebles*	Stobo Castle	3·02	120
,,	Lowestoft Sec. School ...	3·29	168	*Berwick*	Marchmont House ...	2·57	107
,,	Bury St. Ed., Westley H.	4·48	225	*E. Loth.*	North Berwick Gas Wks.	1·50	73
Norfolk	Sandringham Ho. Gdns.	4·00	193	*Midl'n.*	Edinburgh, Blackf'd. H.	1·53	75
Wilts.	Aldbourne	3·77	179	*Lanark*	Hamilton W. W., T'nhill	2·98	111
Dorset	Creech Grange... ...	3·95	144	*Ayr*	Prestwick	3·60	140
,,	Beaminster, East St. ...	4·30	169	,,	Glen Afton, Ayr San. ...	3·49	89
Devon	Teignmouth, Den Gdns.	2·24	114	*Renfrew*	Greenock, Prospect Hill	3·80	85
,,	Ilfracombe	6·57	244	*Bute*	Rothesay, Ardencraig ...	4·14	102
,,	Princetown	10·32	202	*Argyll*	Morven, Drimnin ...	4·40	78
Cornwall	Bude, School House ...	3·72	151	,,	Poltalloch	4·23	93
,,	Penzance	4·34	148	,,	Inveraray Castle ...	5·07	79
,,	St. Austell	4·04	127	,,	Islay, Eallabus	4·47	107
,,	Scilly, Tresco Abbey ...	2·04	80	,,	Tiree	2·94	79
Somerset	Taunton	2·67	135	*Kinross*	Loch Leven Sluice ...	1·81	70
Glos.	Cirencester	4·73	207	*Fife*	Leuchars Airfield ...	1·45	75
Salop	Church Stretton ...	5·94	282	*Perth*	Loch Dhu	5·99	105
,,	Shrewsbury, Monkmore	4·77	293	,,	Crieff, Strathearn Hyd.	3·19	112
Worcs.	Malvern, Free Library...	4·64	240	,,	Pitlochry, Fincastle ...	1·91	76
Warwick	Birmingham, Edgbaston	5·10	259	*Angus*	Montrose Hospital ...	1·50	75
Leics.	Thornton Reservoir ...	5·17	286	*Aberd.*	Braemar	2·57	102
Lincs.	Boston, Skirbeck ...	4·44	252	,,	Dyce, Craibstone ...	2·26	93
,,	Skegness, Marine Gdns.	4·21	233	,,	New Deer School House	4·04	160
Notts.	Mansfield, Carr Bank ...	4·51	245	*Moray*	Gordon Castle	1·97	79
Derby	Buxton, Terrace Slopes	10·09	311	*Nairn*	Nairn, Achareidh ...	1·29	61
Ches.	Bidston Observatory ...	5·60	232	*Inverness*	Loch Ness, Garthbeg ...	2·81	91
,,	Manchester, Ringway...	6·21	274	,,	Loch Hourn, Kinl'hourn	10·27	115
Lancs.	Stonyhurst College ...	8·32	218	,,	Fort William, Teviot ...	5·12	80
,,	Squires Gate	4·55	168	,,	Skye, Glenbrittle ...	...	...
Yorks.	Wakefield, Clarence Pk.	3·29	206	,,	Skye, Duntulm... ...	3·95	86
,,	Hull, Pearson Park ...	3·46	201	*R. & C.*	Tain, Mayfield... ...	1·05	46
,,	Felixkirk, Mt. St. John...	3·25	179	,,	Inverbroom, Glackour...	6·36	144
,,	York Museum	3·16	194	,,	Achnashellach	8·72	127
,,	Scarborough	3·01	168	*Suth.*	Lochinver, Bank Ho. ...	4·58	132
,,	Middlesbrough... ...	2·64	159	*Caith.*	Wick Airfield	3·25	130
,,	Baldersdale, Hury Res.	3·82	149	*Shetland*	Lerwick Observatory ...	4·19	139
Norl'd.	Newcastle, Leazes Pk....	3·69	186	*Ferm.*	Crom Castle	3·74	134
,,	Bellingham, High Green	2·40	100	*Armagh*	Armagh Observatory ...	3·87	157
,,	Lilburn Tower Gdns. ...	2·55	108	*Down*	Seaforde	5·11	186
Cumb.	Geltsdale	4·46	159	*Antrim*	Aldergrove Airfield ...	4·71	190
,,	Keswick, High Hill ...	6·70	158	,,	Ballymena, Harryville...	5·52	177
,,	Ravenglass, The Grove	7·20	214	*L'derry*	Garvagh, Moneydig ...	5·34	180
Mon.	A'gavenny, Plâs Derwen	6·65	260	,,	Londonderry, Creggan	6·27	190
Glam.	Ystalyfera, Wern House	11·13	255	*Tyrone*	Omagh, Edenfel ...	4·47	147

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